Musical creation with multisensorial interactive simulation of physical objects

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Introduction

Computer systems dedicated to musical creation are founded on two main paradigms:

- Production and treatment of sound signals considered as musical material (sound synthesis),
- Production or assisted production of musical works using musical (natural or synthetic) material (computer assisted composition).

The synthesis of sound signals is supported by classical methods: Fourier synthesis, granular synthesis, frequency modulation, general signal processing methods, etc. These methods are generally denoted as "signal modeling methods". Computer assisted composition, from its side, considers the musical structure as a system of relations between the perceptual and musical parameters of musical elements. Both resort to concepts and tools which are now classical: graphical and interactive interfaces for editing, analysis, treatment, notation, real time systems, gestural control systems, network systems, etc. But most of these systems and of the approaches that determine their conception remain quite conventional concerning the artistic object and its creation process. Even if they bring into play more and more systematically interactivity, real / virtual mixing, multimedia and network installations, in fact, they don't radically explore the new paradigms allowed by new technologies.

The starting point of the approach developed by ACROE since the 1980's, with the multisensorial interactive simulation of physical objects, is precisely to reconsider at a basic level the artistic object and creation process themselves in the light of computer concepts and techniques. Firstly, the computer is seen not as a simple means to create new sounds, extending the traditional techniques, but as a means to create new artifacts: virtual objects with which we can interact in a complete and multisensorial manner. We can play with them by our gestures while they respond us through acoustical, visual and tactile phenomena. Consequently the sound creation and the composition process are deeply modified since we have to create objects, play and experiment them and then compose, not sounds, but complex multi level structured objects.

In this paper, we will quickly introduce the tools we developed in our laboratory:

- The physical modeling system CORDIS – ANIMA,
- The force-feedback gestural transducers TGR,
- The GENESIS graphical interface for the musical creation with CORDIS – ANIMA.

Then, we will present the methodology for the sound objects modeling, a description of several models corresponding to the main categories of sound production and some first examples of using physical modeling to create large musical sequences.

The CORDIS – ANIMA system and the force-feedback gestural transducers

The CORDIS – ANIMA system is both a modeling language and a simulation system.

In its first function it allows modeling of anything as networks made of two types of components:

- Components called "material elements" characterized at each instant by a dynamic state (position and velocity in a mono or multidimensional space) and having an intrinsic property: its inertia
- Components called "link elements" linking in a bi-directional way two material elements and applying to them opposite forces depending on their relative positions / velocities, according to a viscoeleastic law.

A CORDIS – ANIMA object is then a network of interacting material elements.

In its second function, CORDIS – ANIMA allows to simulate multisensorial objects thanks to:

- Algorithms associated to each component according a set of basic physical like laws (punctual mass, linear elasticity and/or viscosity, non-linear interaction laws)
- Input and output interfaces controlling sensors, actuators and display devices immerged in the real word (force and displacement sensors installed on gestural devices, loudspeakers, visualization screens).

This system allows the simulation of physical objects like those we encounter in our natural environment (solid, fluid, deformable, moving, vibrating objects, etc.).

But the range of the objects that can be modeled is not limited to this. The spatio-temporal scale and the physical nature of the processes are not necessary the ones of acoustical phenomena. So, it is possible to simulate as well every kind of process that can be described as structures of interacting entities at which we can associate properties comparable to the basic inertia, elasticity, viscosity, non-linearity.

The gestural force-feedback devices (TGR) come to complete acoustic and visual interfaces in order to allow a full multisensorial interaction with the virtual objects. The TGR are mechanical devices doted of sensors and motors. With the sensors (force or displacement sensors) they give to the computer a signal representing the gestural action. Thanks to the motors installed on each freedom degree, they can produce under the control of the model in the computer, the mechanical phenomena for the tactile perceptions.

In fact, a CORDIS – ANIMA object is a network of elementary interacting objects... including the "multisensorial human being".

Finally, the CORDIS – ANIMA system is at the end a software that can be implemented on any computer with a sufficient power for simulation calculations. It is used for several

applications: music creation, animated image creation, general virtual reality purposes. In this paper, we refer to its use for musical creation thanks to the GENESIS graphic interface developed in our laboratory for this application.

Models and systems for musical creation

In order to model objects for sound synthesis, one must start with a first macroscopic analysis of the physical chain producing sound events from a gestural action. It is generally composed of:

- A vibrating structure (VS), physical system capable to get vibrating behaviors at the audio frequency,
- An excitation device making a transfer of the gestural energy to the VS.
- A local environment (like resonance board in the string instruments). Transferring acoustical energy from the VS to the aerial environment, it play also a crucial role in allowing several VS to be combined in a complex structure.
- A global environment corresponding to the room in which the instruments, the players and the listeners are. It has its own properties due to the aerian diffusion and propagation and to the interaction of the acoustic *waves* with the walls.

For each of them, we have studied a set of basic models. By combination of these components, complete virtual instruments can be built. We will present and discuss some examples:

Models of strings and air columns

The basic model for strings and air columns is made of a chain with masses linked with spring-damper elements. This chain can be closed or not at its extremities, giving the basic properties of strings (when closed at the two extremities) or pipes (when closed at only one extremity). The modal properties of the object are completely determined by the number of masses and the values of inertia, elasticity and viscosity parameters.

Models of plates and membranes

In the same way, plates and membranes can be simulated with a grid with a two or tree dimensional topologic structure of connection. The edge conditions are defined through the nature and the parameters given to the edge elements.

Models of inhomogeneous strings

A simple way to model vibrating structures with specific inharmonic spectrum is to give inhomogeneous value to the inertia and viscoelastic parameters along a string. We can for example obtain the spectral structure of a bell by giving values of inertia following the shape of a bell. More generally, we can mathematically force this spectrum for an inhomogeneous string to follow an arbitrary given structure.

Models of struck strings, membranes or plates

Percussive mechanisms can be very easily simulated using individual masses as hammers and non-linear links simulating collision interactions, between them and a chosen point on the vibrating structure.

Models of bowed strings

A non-linear viscosity as in a bow – string interaction, represented by a specific non-linear function (force in function of velocity), placed between a moving mass and any point of a vibrating structure allows to simulate bowed strings as well as bowed plates, beams, etc. A "bowed" air column gives a way to simulate wind instruments.

Models of plucked strings

Plectrum can be simulated using non-linear spring-like interactions.

Models of resonance chamber

A resonance chamber is in fact a vibrating structure. Several particular features give it its specific status: it has its own modal structure, the damping is important, its inertia is great compared to the one of vibrating structures connected to it. Several vibrating structures can be connected to such a chamber, allowing to create complex "polyphonic" instruments like guitar, harp, piano.

Brownian particles

A wide variety of natural sound phenomena are produced by sets of great number of particles in interaction. The water or wind sounds can be produced putting together a great number of masses with collision interactions into a recipient. The Brownian movements obtained produce noises that can be colored thanks to resonance chambers.

Generally speaking, all kind of natural physical process can be modeled through this schema. It is also possible to determine the matter (wood, glass, metal, etc.) of the objects by adjusting their visoelastic parameters. In each case, the modeling resort to a systemic approach in the sense that the desired phenomenological result must be understood as the emergence of the local properties of the components and of the structure in which they are assembled.

But the more important relevance of this method is that it allows modeling of not only micro phenomena (elementary sound phenomena for example), but also of phenomena and process at macro spatio – temporal scales.

Physical modeling for musical composition

Using the previous basic models with time constants that correspond to macro-temporal process, one can generate a wide variety of large temporal scale events. They can be used as material at the level of the musical composition. More generally the musical composition can be thought as a construction of a macro dynamic model implying a set of various sub-models in specific relations. Since the basis of the language (with its four categories of elements: inertia, elasticity, viscosity and non-linearity) is complete, we can be sure that any arbitrary structural construction can be generate.

As a conclusion, we can say that the multisensorial simulation of physical objects is not only a new method to create sounds, but a general paradigm for musical and multisensorial creation. It introduces new perspectives: the creation of the microstructure and of the macrostructure at different scales of the work can be supported by a unique and unified system of concepts. The interaction paradigm is present at all the levels: between parts of objects, between different scales of them and between them and the subjects.